PATENT ABSTRACTS OF JAPAN

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(54) OPTICAL WAVEGUIDE DEVICE AND MANUFACTURING METHOD THEREFOR

(57)Abstract:

PROBLEM TO BE SOLVED: To manufacture a quartz-based optical waveguide device which is free of sinking of a core in a lower clad layer, slanting, etc., and has extremely small polarization dependency with high yield and good reproducibility.

SOLUTION: In a quartz-based optical waveguide comprising a lower clad layer, a core, and an upper layer formed on an Si substrate, the lower clad layer and upper clad layer are formed of BPSG films. A sinking preventive layer is formed of two or more layers with relatively high softening temperature below the core so as to suppress the sinking and tilting of the core owing to softening of the lower clad layer.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
This invention relates to the optical waveguide device used for optical communication etc., and its manufacture approach.
[Background of the Invention]
[0002]
Commercialization expansion of an optical transmission system is progressing by the butt with the rapid spread of the Internet. The 2.5 Gb/s system which can transmit 30,000 or more circuits by the usual telephone line is introduced in many areas, and the method which attains large capacity-ization several times multiplex [of this] with wavelength multiplex system has already come to be put in practical use in accordance with expansion of information-transmission capacity. From the wavelength multiplexing of early **** level, the high density wavelength multiplex system to 80 wave level has come to be commercialized by current. In such a wavelength-multiplex-optical-telecommunications method, the splitter for carving into the signal of different wavelength two or more signal light which has different wavelength from the multiplexing machine for introducing into one optical fiber and the lightwave signal by which wavelength multiplexing was carried out becomes important, and the array waveguide grid (AWG) attracts attention as the example. As shown in drawing 7 , the array-like optical waveguide which has the optical-path-length difference with AWG same among the star couplers 22 and 24 of two I/O is formed, and when array waveguide plays a role of a high order diffraction grating shows the function of multiplexing/demultiplexing. AWG in which the optical waveguide of a quartz system was formed on the silicon (Si) substrate thru/or the quartz substrate is already commercialized, and is used for the actual optical transmission system.
[0003]
However, in the quartz system optical waveguide device which used Si for the substrate, the thermal stress resulting from the difference in the coefficient of thermal expansion of Si and a quartz system waveguide ingredient occurs. A birefringence occurs inside the quartz system film with this stress, and the problem that propagation properties will differ between TE and the TM mode as a result is latent. Like especially an AWG device, with the device with which adjacent channel wavelength spacing has a narrow steep transmitted wave length spectrum, the polarization dependence loss (PDL) also with a big gap of the wavelength property between very slight TE and the TM mode arises, and it becomes a practically big problem. In order to reduce PDL, it is necessary to reduce the thermal stress of the quartz system film which constitutes waveguide. It is possible by adjusting dopant concentration, such as Lynn (P) in the film, and boron (B), and bringing a coefficient of thermal expansion close to Si substrate to reduce thermal stress. The approach of forming optical waveguide using the clad which reduced thermal stress by this approach is indicated by the patent reference 1, and according to nonpatent literature 1, it has succeeded in Suzuki's and others reducing the gap (deltalambda) of transparency core wavelength which produces the AWG device which reduced stress double refraction by this approach, and is dependent on the mode from the 0.19nm till then to 0.03nm.
[0004]
[Patent reference 1] JP,8-136754,A
[Nonpatent literature 1] Electronics Letters, the 33rd volume, No. 13, 1173-1174 pages, June, 1997 (ELECTRONICS LETTERS, Vol.33, No.13, PP.1173-1174, June, 1997)
[Description of the Invention]
[Problem(s) to be Solved by the Invention]
[0005]
However, by the conventional approach, since the quartz system film which doped P and B to the lower cladding layer at high concentration in order to reduce membrane stress was used, there was a problem that the core in waveguide will

sink in a part of lower cladding layer by elevated-temperature heat treatment after up cladding layer membrane formation. That is, if P and B are doped to high concentration, it will be known that softening temperature will fall, the quartz system film could not bear elevated-temperature heat treatment after up cladding layer membrane formation, but the location of a core changed, or it inclined, and the problem that the property of a device deteriorated arose. Especially in the case of an AWG device, a location gap and inclination of very few cores bring about evils, such as an increment in the cross talk between channels. In order to prevent a location gap and inclination of such a core, forming in the lower cladding layer upper part the pure quartz system film (NSG) which does not contain dopants, such as P and B, is indicated by the patent reference 2. By this approach, since an up cladding layer is formed at an elevated temperature 1000 degrees C or more, sufficient thickness is needed for a NSG layer. However, while softening temperature was highly firm, since stress was also large, NSG brought about the increment in stress in the camber of a substrate, or a waveguide layer, and had a problem of making deltalambda increase. Moreover, since control of a refractive index was difficult for NSG, it had to double the refractive index of others and a cladding layer with NSG, and also had the problem that the class of dopant and the degree of freedom of an amount became small.
[0006]
This invention aims to let a polarization dependency offer the optical waveguide device which was small excellent in a device property and the homogeneity within a substrate side, and its manufacture approach.
[0007]
[Patent reference 2] JP,5-157925,A
[Means for Solving the Problem]
[0008]
In order to solve the above-mentioned technical problem, in the invention in this application, the following optical waveguide device and its manufacture approach are indicated.
[0009]
It is the optical waveguide device characterized by this invention having the subduction prevention layer which it is phosphorus and the quartz system film of boron which added either at least, and softening temperature becomes from a high ingredient rather than said up cladding layer between said lower cladding layers and said cores in the optical waveguide device which carries out a lower cladding layer, a core, and an up cladding layer on a silicon substrate.
[0010]
Moreover, it sets to the optical waveguide device which carries out a lower cladding layer, a core, and an up cladding layer on a silicon substrate. They are phosphorus and the quartz system film of boron which added either at least between said lower cladding layers and said cores. Are below the 1st subduction prevention layer which softening temperature becomes from a high ingredient rather than said up cladding layer, and this 1st subduction prevention layer, and consisting of the 2nd subduction prevention layer which consists of an ingredient with still higher softening temperature rather than this 1st subduction prevention layer It is the optical waveguide device by which it is characterized.
[0011]
It is the optical waveguide device characterized by an up cladding layer consisting of phosphorus and quartz system film of boron which added either at least at least among said cladding layers in the above-mentioned optical device.
[0012]
It is the optical waveguide device characterized by for the sum of the weight concentration of the phosphorus element in the quartz system film which forms said up cladding layer in the above-mentioned optical waveguide device, and a boron element being less than [more than 6.2wt%15wt%], and the membrane stress of said quartz system film being 3x107Pa or less.
[0013]
It is the optical waveguide device characterized by for the sum of the weight concentration of the phosphorus element in the quartz system film which forms said up cladding layer in the above-mentioned optical waveguide device, and a boron element being less than [more than 8.8wt%15wt%], and the gap of transparency core wavelength depending on polarization of said optical waveguide device being 0.03nm or less.
[0014]
It is the optical waveguide device according to claim 3 characterized by for the sum of the weight concentration of the phosphorus element in the quartz system film which forms said up cladding layer preferably, and a boron element being 12 - 14wt%, and the membrane stress of this quartz system film being 8.3x106Pa or less.
[0015]
It is the optical waveguide device characterized by making boron element weight concentration into 3 - 11wt% for phosphorus element weight concentration 4 - 12wt% still more preferably.
[0016]

Said optical waveguide device can use said optical waveguide device as a waveguide type light interferometer.
[0017]
The optical device of this invention can contain the array waveguide skeleton pattern optical multiplexer/demultiplexer which has the 1st slab waveguide which connected at least one or more input waveguides, and the 2nd slab waveguide which connected at least one or more output waveguides to the both ends of array waveguide.
[0018]
This invention on a silicon substrate A lower cladding layer, a subduction prevention layer, a core, It is the manufacture approach of an optical waveguide device that have an up cladding layer in this order, and said subduction prevention layer consists of an ingredient with high softening temperature rather than said up cladding layer. It has the process which forms a lower cladding layer, a subduction prevention layer, a core, and an up cladding layer on a silicon substrate at this order. In the manufacture approach of the optical waveguide device which forms only both said lower cladding layer and said up cladding layer, or said up cladding layer with phosphorus and the quartz system film of boron which added either at least Membranes are added and formed. said quartz system film -- a CVD method -- using -- the sum of the weight concentration of a phosphorus element and a boron element -- less than [more than 6.2wt% 15wt%] -- It is the manufacture approach of the optical waveguide device which equips the account quartz system film of back to front with the process which performs 800-degree-C or more heat treatment of 1000 degrees C or less, and is characterized by the membrane stress of said quartz system film being 3x107Pa or less.
[0019]
This invention on a silicon substrate Moreover, a lower cladding layer, a subduction prevention layer, a core, It is the manufacture approach of an optical waveguide device that have an up cladding layer in this order, and said subduction prevention layer consists of an ingredient with high softening temperature rather than said up cladding layer. It has the process which forms a lower cladding layer, a subduction prevention layer, a core, and an up cladding layer on a silicon substrate at this order. In the manufacture approach of the optical waveguide device which forms only both said lower cladding layer and said up cladding layer, or said up cladding layer with phosphorus and the quartz system film of boron which added either at least Membranes are added and formed. membrane formation of said quartz system film -- a CVD method -- using -- the sum of the weight concentration of a phosphorus element and a boron element -- less than [more than 8.8wt%15wt%] -- It is the manufacture approach of the optical waveguide device characterized by setting to 0.03nm or less the gap of transparency core wavelength which equips the account quartz system film of back to front with the process which performs 800-degree-C or more heat treatment of 1000 degrees C or less, and is dependent on polarization of said optical waveguide device.
[0020]
In the manufacture approach of the above-mentioned optical device, it is the manufacture approach of the optical waveguide device characterized by for said subduction prevention layer to consist of the 2nd subduction prevention layer which is downward further rather than the 1st subduction prevention layer which consists of an ingredient with softening temperature higher than said up cladding layer, and this 1st subduction prevention layer, and consists of an ingredient with still higher softening temperature rather than this 1st subduction prevention layer.
[0021]
Said optical waveguide device can be used as a waveguide type light interferometer.
[0022]
Moreover, the manufacture approach of an optical waveguide device given in either of claims 10-12 characterized by making boron element weight concentration into 3 - 11wt% for phosphorus element weight concentration 4 - 12wt%.
[0023]
It is the manufacture approach of the optical waveguide device characterized by making the sum of the membrane formation temperature of 400 degrees C, the heat treatment temperature of 880 degrees C, and the weight concentration of a phosphorus element and a boron element into 12 - 14wt%.
[0024]
The ordinary pressure CVD method which disassembles tetraethyl orthochromatic silicate into membrane formation of said up cladding layer and a lower cladding layer by ozone can be used.
[0025]
Moreover, that softening temperature inserts in the lower part of a core the high subduction prevention layer which can also adjust a refractive index and stress compared with a clad, or by inserting the high subduction prevention layer of softening temperature in the bottom of this subduction prevention layer further, problems, such as core **** to a lower cladding layer and an inclination, were solved, the location gap of a core was prevented, configuration homogeneity could be made high, and the property of a waveguide device improved and excellent article yield's improved.
[Effect of the Invention]
[0026]

As shown above, the optical waveguide device which whose polarization dependency was very small and was excellent in the high production stability of the degree of freedom of refractive-index control of a clad with this invention became producible. moreover, the location precision of a core is high -- high -- it became possible to produce a yield low polarization dependence optical waveguide device.
[Best Mode of Carrying Out the Invention]
[0027]
The gestalt of operation of the invention in this application is explained more to a detail using a drawing etc. below.
[0028]
Drawing 1 is the production process Fig. showing the first operation gestalt of this invention. The ordinary pressure chemical-vapor-deposition method (APCVD by TEOS-O3 law) which disassembles the organic source which consists of tetraethyl orthochromatic silicate (Si4 (OC2H5)) by ozone (O3) on a silicon substrate 1 is used. The subduction prevention layer 5 which consists of quartz system film (PSG:SiO2+P2O5) which added P after forming the lower cladding layer 2 with the quartz system film (BPSG:SiO2+P2O5+B-2 O3) which added phosphorus (P) and boron (B) was formed. Next, the core layer 7 which consists of quartz system film (GPSG:SiO2+P2O5+GeO2) which added P and germanium (germanium) was formed, the core layer 7 was etched into the desired pattern using a photolithography and reactive ion etching (RIE), after forming the core 3 of a channel mold, the up cladding layer 4 was formed and flush type quartz system optical waveguide was formed. In addition, annealing treatment was performed after class membrane formation. In addition, in addition to this, one thru/or the quartz system ingredient containing two or more dopants of ** or the SiON film, an SiN film, a polymer system, etc. can be chosen as core materials at any cost among P, germanium, or B. The refractive index of a core layer 7 is controlled by adjusting the concentration of germanium etc. to become desired relative index difference to the refractive index of a clad. In addition, the same thing of the refractive index of the lower cladding layer 2 and the up cladding layer 4 is desirable on account of light wave control.
[0029]
Thus, the sectional view of the produced waveguide device is shown in drawing 2 . The problem of subduction of the core 3 at the time of up cladding layer heat treatment or an inclination is suppressed. Since etching of a part is depressed at the time of etching processing of the core 3 by RIE, it will sink if it runs through the prevention layer 5 and the BPSG membrane layer under it is reached, and the effectiveness of the prevention layer 5 decreases, the subduction prevention layer 5 cannot be made not much thin. Conversely, since it will sink and the effect of the increment in stress by the prevention layer 5 will appear if it thickens, the thickness of this subduction prevention layer 5 is good to take into consideration dispersion in the field of the amount of RIE etching at the time of core processing, and to take to about 0.2-5 micrometers. The reason using PSG as an ingredient of the subduction prevention layer 5 is because it is possible to prevent subduction of a core in the first place if softening temperature is the process of 900-degree-C or less extent more highly than BPSG, and is because it can adjust when a refractive index adjusts P concentration to the second, and it can bring close to the lower cladding layer 2 or the up cladding layer 4. Moreover, it is because stress can be reduced compared with the quartz system film (NSG) with which the dopant is not added by adding P to the third. Although it sank by this example from the above reason and PSG was used as an ingredient of the prevention layer 5, dopants, such as P, B, germanium, and a fluorine (F), may be appropriately adjusted so that it may have the above-mentioned description.
[0030]
One more drawing 3 is the sectional view showing another operation gestalt. In addition to the configuration shown in drawing 2 , this configuration inserts the second subduction prevention layer 6 with still higher softening temperature directly under the subduction prevention layer 5, and heightens the effectiveness over subduction of a core further from drawing 2 . This configuration also sinks and it sinks before membrane formation of the prevention layer 5, and since it is only what inserted the prevention layer 6, it is easily realizable. For example, by using the quartz system film (NSG) without a dopant for the subduction prevention layer 5 at PSG and the subduction prevention layer 6, the core 3 was able to sink and the problem of ****** was able to be suppressed completely. The effectiveness of NSG that softening temperature suppresses subduction of a core etc. highly very much compared with BPSG which forms a clad is high. However, since a very large thing and control of a refractive index are difficult also for stress, it is important to form membranes in the range which can suppress subduction of a core as thinly as possible, and to reduce the effect of change on stress or the effective refractive index of waveguide as much as possible. With this operation gestalt, the almost same stress and effective refractive index as the time of sinking, forming NSG by 0.1 micrometers or more 0.3 micrometers or less as a prevention layer 6, and there being no NSG could be realized, and subduction of a core etc. was able to be completely suppressed by the process 1000 degrees C or less. In addition, since it sinks without the subduction prevention layer 5, it may sink when the prevention layer 6 is formed directly under a core, its etching may be depressed with the field internal division cloth of the amount of etching at the time of etching processing of the core by RIE since the prevention layer 6 is formed thinly, and it may run through the prevention layer 6, it is important to

make it two-layer structure with the subduction prevention layer 5. The subduction prevention layer 5 close to a core can also reduce stress while being able to adjust a refractive index with a BPSG clad by adjusting P concentration etc. using ingredients, such as PSG. By inserting the two-layer subduction prevention layers 5 and 6 it is indicated to drawing 3 that described above, adjustment of stress and a refractive index can be taken, the margin of the amount of etching at the time of etching processing of a core is taken into consideration, and structure where effectiveness is very high can be realized to core subduction. Although it sank in drawing 3 here and PSG and NSG were mentioned as the example of the prevention layers 5 and 6, respectively, you may be an SiN film or the SiON film at the thing and the subduction prevention layer 6 which do not restrict to this if there is effectiveness equivalent to it, sank in the subduction prevention layer 5 by explanation of drawing 2 , and were mentioned as other examples of the prevention layer 5.

[0031]

Next, deltalambda was evaluated using the above-mentioned manufacture approach. APCVD according to TEOS-O3 to a silicon substrate top -- 15 micrometers of BPSG monolayers were deposited using law. After film deposition performed annealing treatment. The membrane formation temperature used in this experiment, annealing temperature, and annealing time amount are shown in Table 1.

[0032]

[Table 1]

成膜条件

条件	成膜温度(℃)	アニール温度(℃)	アニール時間(h)
A	３８０	８００	０．５
B	４００	８００	０．５
C	４００	８８０	３
D	４５０	８８０	３
E	４００	１０００	３

[0033]

The relation between the sum (it considers as P concentration +B concentration below) of the weight concentration of P element when changing the addition of P and B using condition A-E of Table 1 and B element and membranous stress is shown in drawing 4 . In drawing 4 , forward pulls membrane stress, negative shows compression, and condition A-E expresses condition A-E in Table 1. Measurement of membrane stress was performed by measuring the amount of camber of a substrate.

[0034]

As shown in drawing 4 , P concentration +B concentration and the relation of membrane stress are linearity, and by controlling concentration showed that stress was appropriately controllable. Moreover, as for stress, it turned out that it is dependent also on process parameters, such as membrane formation conditions and annealing conditions, and it necessary to choose suitable additive concentration according to a process parameter.

[0035]

It is necessary to hold down PDL to 0.3dB or less practically in a transmitted wave length band in an AWG device. If, as for PDL, the proportionality constant takes into consideration proportionally that it is number -10dB/nm in approximation to deltalambda, it is necessary to hold down the absolute value of deltalambda to 0.03nm or less. What is necessary is to just be set to deltaL/mxB<=0.03nm since it is delta lambda=delta L/mxB. deltaL is [the order of diffraction and B of an optical-path-length difference and m] the differences of the effective refractive index of a birefringence, i.e., TM and TE, here. For example if deltaL=60.73micrometer and m= 57 [a value about general to delta L and m is used, and], it may be necessary to be sigma<=8.3x106Pa from B=Ksigma. sigma was membrane stress here, and K is an opto elastic constant and used K=3.4x10-12Pa-1. However, in order to optimize deltalambda, it is necessary to care about that it cannot determine only by the membrane stress of a monolayer, but deltalambda may change with the heat history of each class, the layer structures of a device, etc.

[0036]

The P concentration +B concentration when changing the addition of phosphorus (P) and boron (B) using condition A-E of Table 1 and the relation of deltalambda are shown in drawing 5 . As shown in drawing 5 , P concentration +B concentration and deltalambda were linearity, it was not dependent on polarization by controlling concentration

appropriately, i.e., it turned out that the optical waveguide whose deltalambda is about 0nm can be created. In the range whose annealing temperature are 380-450 degrees C, the range, i.e., the membrane formation temperature, of Table 1, and is 800-1000 degrees C, it turned out that the P concentration +B concentration from which deltalambda is set to 0.03nm or less is contained in the range of 8.8wt(s)% - 15wt%.
[0037]
In addition, when stress was 3x107Pa or less in the device without an optical interferometer, it was enough, and the P concentration +B concentration at that time was 6.2wt(s)% - 17.6wt% from drawing 4 .
[0038]
However, since the water resisting property deteriorated remarkably and the propagation loss deteriorated with time amount when P concentration +B concentration exceeded 15wt(s)%, as for P concentration +B concentration, considering as less than [15wt%] is desirable.
[0039]
the BPSG film with which having set the maximum temperature of annealing as 1000 degrees C here added P and B of high concentration which approaches the coefficient of thermal expansion of Si substrate -- FHD -- when it processes at the elevated temperature 1200 degrees C or more generally used by law etc., it is for a propagation loss to increase according to causes, such as phase splitting and a segregation. Moreover, since an up cladding layer would not soften enough if annealing temperature becomes lower than 800 degrees C and **** between narrow cores became difficult, 800 degrees C was made into the minimum.
[0040]
The 16-channel AWG device with a frequency spacing of 100GHz which consists of a waveguide cross-section configuration shown in drawing 3 using the membrane formation conditions of the conditions C of Table 1 was actually produced. A lower clad and up clad thickness set to 15 micrometers, it was referred to [at the subduction prevention layer 5] as NSG0.3micrometer PSG3micrometer and the subduction prevention layer 6, and the core set width of face and height to 5.5 micrometers. Moreover, to the refractive index of a clad, the refractive index of a core was high, and it was set up so that relative index difference might become about 0.7%. The stress which sets up P and B element concentration sum so that it may become 13.0wt(s)%, and is computed from substrate camber was 3x106Pa. As a result of measurement, deltalambda was an average of 0.01nm or less in the wafer side, and its dispersion within a field was also very as good as less than **0.01nm. If the precision of P+B concentration is taken into consideration, it will be thought that dispersion between wafers is also suppressed sufficiently small. As shown in drawing 6 , the cross talk between [of a total of 16 channels] adjacent channels was as good as -26dB or less. PDL was an average of 0.14dB or less. Moreover, most deterioration of an exterior [after / 1000 hour progress] etc. was not seen at 85-degree-C90%, and fluctuation of loss was [whenever / high-humidity/temperature] stable within 0.2dB with the result of the dependability accelerated test evaluation in inside.
[Brief Description of the Drawings]
[0041]
[Drawing 1] Cross-section process drawing showing the manufacture approach of this invention.
[Drawing 2] The cross-section explanatory view showing the example of the configuration of this invention.
[Drawing 3] The cross-section explanatory view showing the example of the configuration of this invention.
[Drawing 4] The explanatory view showing P concentration +B concentration and the relation of membrane stress.
[Drawing 5] The explanatory view showing P concentration +B concentration and the relation of deltalambda.
[Drawing 6] The explanatory view showing the measurement result of the AWG device by this invention.
[Drawing 7] The top view showing the conventional array waveguide grid.
[Description of Notations]
[0042]
1: Si substrate
2: Lower cladding layer
3: Core
4: Up cladding layer
5: Subduction prevention layer
6: Subduction prevention layer
7: Core layer

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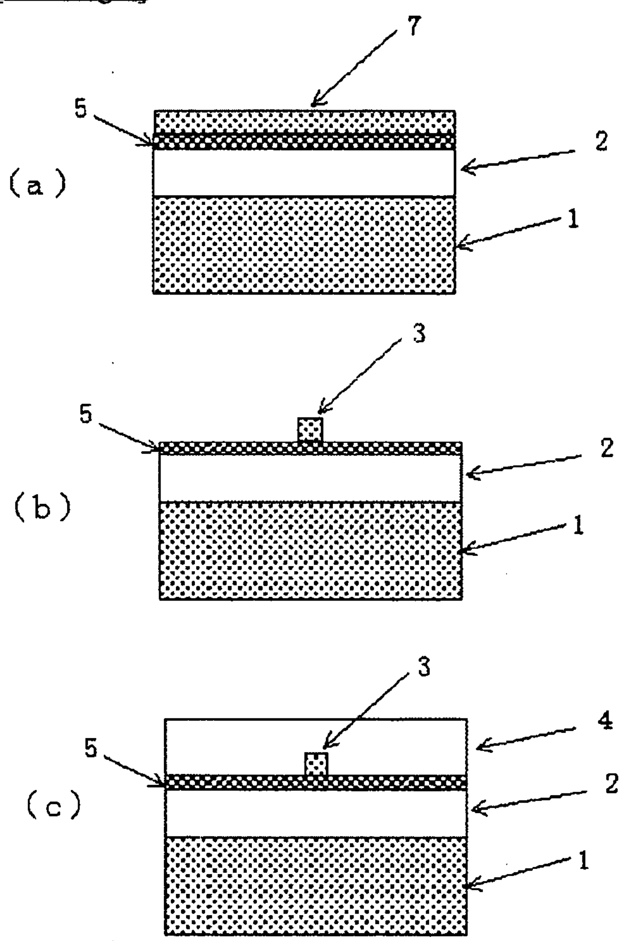
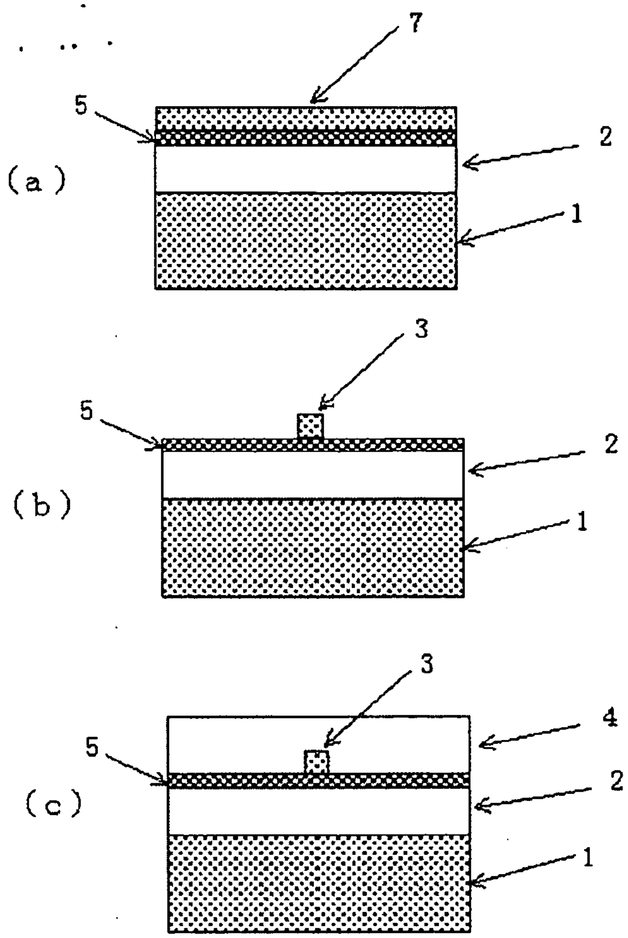
DRAWINGS

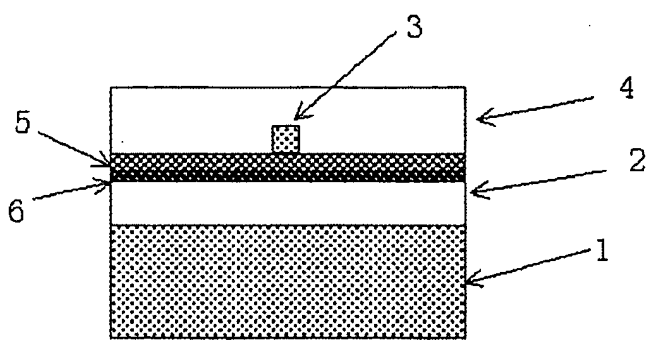
[Drawing 1]



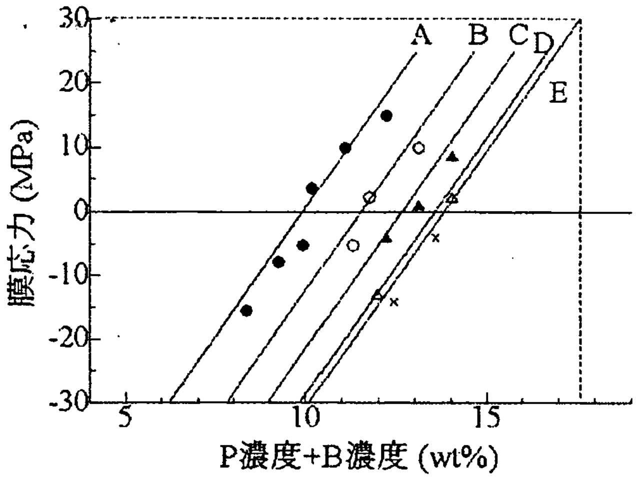
[Drawing 2]



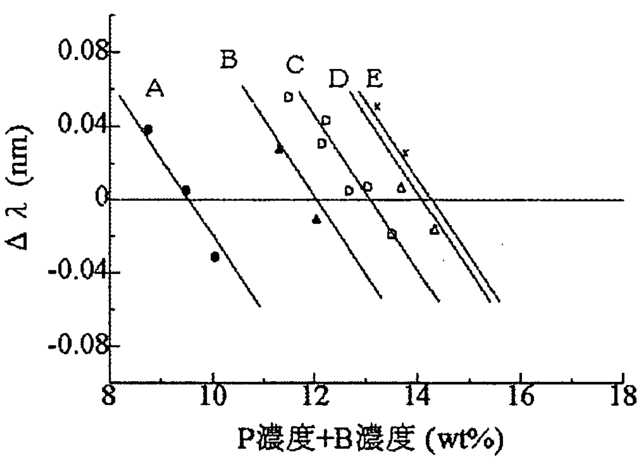
[Drawing 3]



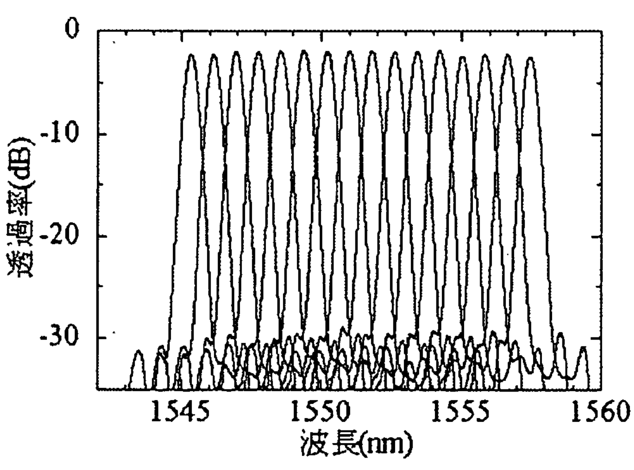
[Drawing 4]



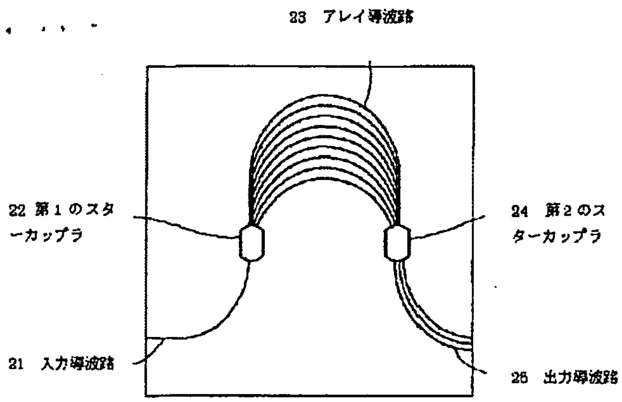
[Drawing 5]



[Drawing 6]



[Drawing 7]



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